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Abstract

A key narrative within climate change science is that conserving and improving soil carbon through agricultural practices can contribute to agricultural productivity and is a promising option for mitigating carbon loss through sequestration. This paper examines the potential disconnect between science and practice in the context of communicating information about soil carbon management. It focuses on the information producing process and on stakeholder (adviser, farmer representative, policy maker etc) assessment of the attributes credibility, salience and legitimacy. In doing this it draws on results from consultations with stakeholders in the SmartSOIL project which aimed to provide decision support guidelines about practices that optimise carbon mitigation and crop productivity. An iterative methodology, used to engage stakeholders in developing, testing and validating a range of decision support guidelines in six case study regions across Europe, is described. This process enhanced legitimacy and revealed the importance, and the different dimensions, of stakeholder views on credibility and salience. The results also highlight the complexities and contested nature of managing soil carbon. Some insights are gained into how to achieve more effective communication about soil carbon management, including the need to provide opportunities in projects and research programmes for dialogue to engender better understanding between science and practice.

Keywords: soil carbon, soil organic carbon, farmers, advisers, agricultural practices, mitigation, credibility, salience, legitimacy,

1. Introduction

Debates in rural contexts about the authoritative status and legitimacy accorded to scientific knowledge have been played out in contested arenas of conservation agriculture, diffuse pollution, GMOs, animal disease, pollinators and agri-environmental management (Blackstock et al., 2010, Fish et al., 2003, Maye et al., 2014, Maderson and Wynne-Jones, 2016, Sumberg and Thompson, 2012). More widely, recognition of science's institutionalised power and its denial of the legitimacy of other knowledges has led to a more democratic model of science and society (Wynne, 1996, Whatmore, 2009). At the same time a growing appreciation of the complexity of social-ecological systems has prompted calls for a more appropriate science that "will be based on the assumptions of unpredictability, incomplete control, and a plurality of legitimate perspectives" (Funtowicz and Ravetz, 1995 p1). A redefined position of scientific knowledge is also proposed for contributing to the negotiation processes in the context of competing claims on natural resources (Giller et al., 2008). This paper is situated against this theoretical backdrop. It examines the challenges of communicating information about the complex and uncertain science behind soil carbon management and draws on the notions of credibility, salience and legitimacy elaborated in the Science and Technology literature (Cash et al., 2002).

Conserving and improving soil carbon through agricultural land management provides an important opportunity to address the major global challenges of rapid climate change, degradation of soil and water quality and urgent and growing demand for food (Banwart et al., 2014). Soil organic carbon (SOC) supports essential soil functions, prominent among these is the considerable potential for land management strategies for mitigating carbon loss (Desjardins et al., 2005). A number of 'climate-smart' arable land management practices, such as cover crops, crop residues and reduced tillage, have shown potential for carbon sequestration by protecting, maintaining and increasing SOC stocks (Lal, 2003, Smith, 2004, Smith, 2012, Paustian et al., 2016). Many of these practices are also considered to improve soil productivity and profitability of farming systems (Lal, 2006). Thus soil can be managed positively to enhance the multiple benefits that SOC provides (Kahiluoto et al., 2014). As stated by OECD (2015 p.1) "soil organic matter, essentially made of carbon, is not only one of the determining factors of agricultural productivity, and a powerful support to crop resilience and adaptation to climate change, but also a promising option to sequester atmospheric CO_2 captured by photosynthesis".

These are the key narratives associated with soil carbon, they underpin international scientific and political interests in carbon sequestration, articulated for example in IPCC reports (Smith, 2012, Smith et al., 2007b), are central to initiatives such as FAO's Climate Smart Agriculture and France's "4 per 1000" proposal endorsed by the COP 21 Steering Committee in 2015 (OECD, 2015), and are the basis of voluntary and market based measures (Rochecouste et al., 2015, Dumbrell et al., 2016). This framing can be characterised as techno-scientific, based as it is on the underlying assumption that problems are of a technical nature and can be solved with agronomic interventions supported by scientific evidence (Feola et al., 2015). Understanding and removing barriers and increasing the acceptance of soil management using voluntary, compliance and economic measures is seen as a core strategy (Paustian et al., 2016). Accordingly it is assumed that the potential for agricultural practices to sequester carbon and achieve the multiple benefits described can be realised if land managers are persuaded to change practice, and that information plays a central role in this process.

Whilst this behavioural model which assumes an 'information deficit' is widely critiqued (Fleming and Vanclay, 2011, Moser, 2010), the nature and the processes involved in communicating information across the science-practice interface remain of interest. As scholars have argued the quality of the linkage between knowledge and action strongly influences the acceptance of new practices (Vogel et al., 2007). This has been demonstrated extensively in agricultural research projects which endeavour to bridge the so-called divide between scientific or technical solutions and implementation in the field (Carberry et al., 2002, McCown, 2001, Millar and Curtis, 1999). The process of knowledge development influences the substance of the knowledge developed (Jacobson, 2007, McNie, 2007, Pielke Jr, 2007) as such the need to pay attention to internal and external scientific processes and the quality of evidence produced has been highlighted (Van der Sluijs et al., 2008). The requirement for greater sensitivity to farmers' understandings of scientific knowledge when exploring management responses particularly for complex and contested issues has also been identified (Holloway, 1999).

The nature of the linkage is pertinent to the context of climate mitigation and adaptation which is difficult to communicate beyond the scientific community, due to its inherent uncertainty and complexity (Hammill and Tanner, 2011, Moser, 2010, Shackley and Wynne, 1996). This is significant given that managing carbon sequestration is a new and technically complex topic, and according to Dilling and Failey (2013) lacks sufficient supportive information for land managers.

Communicating effectively about soil carbon management presents some particular challenges. Many of the claims and promotional messages are centred on the scientific characterisation of the potential of practices to enhance carbon sequestration (Dilling and Failey, 2013). This can be problematic since soil carbon dynamics are associated with scientific uncertainty and debate concerning not only the effectiveness of practices in enhancing soil carbon but also in the role of soil carbon in mitigation (Powlson et al., 2011, Mackey et al., 2013, Stockmann et al., 2013, Sommer and Bossio, 2014, Söderström et al., 2014, Bradford et al., 2016). Furthermore, the interest in soil carbon is perceived to be driven by a political climate change agenda and not always relevant to farmer interests, priorities or aligned to their beliefs (Arbuckle et al., 2014, Wilke and Morton, 2015, Sumberg et al., 2013).

All these issues create problems with respect to scientific information being perceived as credible, relevant and considerate of everyday lives and priorities of the farming community. They also highlight that, in order to support land managers' information needs concerning soil carbon management, researchers must become more attuned to the process of producing information as well as the ultimate decision context in which information might be used (Dilling and Failey, 2013).

With this in mind this paper seeks to examine the potential disconnect between science and practice in the context of communicating information about soil carbon management. Specifically, it focuses on the information producing process and on stakeholder assessment of the attributes *credibility, salience and legitimacy,* drawing on results from consultations with representatives from the farming community in the SmartSOIL project. This interdisciplinary project aimed to provide scientifically grounded decision support to a range of beneficiaries about practices that optimise carbon mitigation and crop productivity.

2. Conceptualisation –credibility, salience and legitimacy

2.1 Farmer behaviour and communication

Farmers are the group on which the tasks of climate change adaptation and mitigation in agriculture will mainly fall (Berry et al., 2006). As the main agents undertaking these tasks their behaviour influences how and with what success scientifically derived programmes and measures are realised on the ground (Feola et al., 2015). Many studies taking a techno-scientific view have focused on technological, informational, educational, political and attitudinal barriers to implementing adaptation and mitigation practices on the farm (Smith et al., 2007a, Feliciano et al., 2014, Arbuckle et al., 2014, Cook and Ma, 2014, Burbi et al., 2013, Dumbrell et al., 2016). This follows a long tradition of behavioural studies in rural contexts in which factors explaining non-adoption of agronomic practices, innovations and agri-environmental schemes (AES) are evaluated (Feder and Umali, 1993, Knowler and Bradshaw, 2007, Siebert et al., 2006, Prokopy et al., 2008). In response to criticisms that such approaches do not accommodate farmers' diverse rationalities, there has been a shift towards understanding and influencing behaviour in wider terms of socio-cultural influences, identity and social embeddedness and social principles (Feola et al., 2015, Burton, 2004, Vanclay, 2004). Accordingly Fleming and Vanclay (2011 p16) call for social understanding of climate change asserting that "there is no such thing as a barrier to change, only legitimate reasons not to change". Likewise Moran et al. (2013) argue that mitigation win-win messages constructed to persuade farmers to change practices oversimply and neglect socio-cultural aspects of farmer behaviour. In line with this, prominence is increasingly given both in rural and climate mitigation and adaptation contexts to identifying these legitimate reasons by putting more effort into understanding the complexity of farmer decision contexts, as well as to making the process of knowledge production and exchange more effective (McNie, 2007, Hegger et al., 2012, Raymond et al., 2010).

2.2 The science-practice boundaries

In the agricultural setting, the tensions at the interface between science and practice have been the focus of much scholastic work, with attention given to science-farmer relations, specifically the nature of the knowledge they hold, the processes involved in the production and exchange of this knowledge, and the conflict and alignment over the validity and relevance of knowledge constructed in different contexts (Eshuis and Stuiver, 2005). Scientist and farmer communities are characterised by different: epistemologies, ways of framing problems, perspectives informed by values, interests, context, lifeworlds, and experiences (Tsouvalis et al., 2000, Ramisch, 2014, Raedeke and Rikoon, 1997, Turnbull, 1993). Specifically in relation to soil management, differing aims, methods and context of work have been identified in the two communities (Ingram et al., 2010). The notion of boundaries has been used to conceptualise the interface between these communities or domains and to reveal their epistemic divides (Wenger, 1999, Long, 2001, Carlile, 2004, O'Kane et al., 2008).

The Science and Technology literature explores how such boundaries at the science-policy interface between communities of experts and decision makers can be understood and managed (Jasanoff, 1987). According to Cash et al. (2003 p.8086), there is a "prevalence of different norms and expectations in the two communities [experts and decision makers] regarding such crucial concepts as what constitutes reliable evidence, convincing argument, procedural fairness, and appropriate characterization of uncertainty". Based on evaluations of scientific advice and environmental assessments, they assert that scientific information is likely to be more effective in influencing the social responses if it is perceived by relevant stakeholders to be, not only credible, but also salient and legitimate. They suggest that actors on different sides of the science-policy boundary perceive and value the attributes of credibility, salience and legitimacy differently and this makes boundary crossing difficult.

This body of work is pertinent to understanding the quality of linkage between scientific and farming communities with respect to managing soil carbon. Particularly as scientists are being called upon to translate scientific knowledge into practical tools for land managers on, for example, soil function (Doran, 2002), and as farmers and land managers are increasingly targeted by scientists to collaborate in research and to develop these tools (Oliver et al., 2012, de Bruyn and Abbey, 2003).

2.3 Credibility

Credible information is perceived by the users to be accurate, valid, and of high quality. It relates to the nature of the knowledge and methods of its production and perceived validity (Cash et al., 2003). In scientific arenas it refers to the scientific plausibility of the technical evidence and arguments. Status has always been accorded to scientific knowledge, by virtue of its rigour, systemic approach and rationality. However credibility can be interpreted differently in different domains and as such is disputed across boundaries, where there can be conflict, imposition, negotiation, strategic adjustment and compromise over resources and knowledge, particularly concerning what is valid and true knowledge, and what is not. Furthermore, when science enters the social arena of the land manager, knowledge can become contested and negotiated (Long, 2001, Giller et al., 2008).

Credibility has long been known to influence how farmers receive and use information, for example, in studies of acceptance of scientific decision support tools (Carberry et al., 2002), and in providing agronomic and agri-environmental advice (Sutherland et al., 2013, Mills et al., 2016, Ingram, 2008). In such cases farmers' experiences of the efficacy of particular scientifically derived advice and prescriptions do not accord with their own knowledge and observations (Riley, 2008). This can be compounded by conflicting information (Vanclay and Lawrence, 1994). Credibility, in the sense of believability, is evaluated simultaneously through multiple dimensions, including trustworthiness and expertise; although trust often refers to the source of information (people and social institutions) others argue that it is a perceived quality, it does not reside in people, objects or a piece of information (Tseng and Fogg, 1999)

In communicating the impacts and benefits of climate change adaptation and mitigation to farmers, credibility is influenced by limited scientific evidence and uncertainty (Hammill and Tanner, 2011, Harvey et al., 2014). Here according to Moser (2010 p35) uncertainty can stem from the lack of data, lack of adequate theoretical understanding of environmental system interactions and "the unavoidable inadequacy of representing nature's complexity in models". Specifically for soil carbon there are indications that scientifically validated information about sequestration is important to public land managers in USA who look for 'reliable', 'unbiased', and 'the best available science' to help them make decisions about changing practice (Dilling and Failey, 2013). However, the complexity and the contested nature of the soil carbon science suggest that this scientific authority might not be fully available to support recommendations on effective practices for storing SOC.

Uncertainties exist because the carbon sequestration benefits of different practices depend on multiple variables: soil texture, soil taxonomy, climate, management and many other local factors. Furthermore, as SOC responds slowly to changes in agricultural management, most SOC changes require many years to be detectable by present analytical methods, and can only be reliably measured in long-term experiments (Smith, 2012, Smith et al., 2005, Desjardins et al., 2005). Also the relationship between specific practices, soil carbon and yield has not yet been fully established because SOC derived effects are confounded with those of soil management (Schjønning et al., 2009), and other non-carbon related benefits, such as enhanced soil moisture. The scientific ambiguity about the effect of reduced tillage (Baker et al., 2007), no-till (Powlson et al., 2014) and conservation agriculture (Andersson and D'Souza, 2014) on SOC and yield, demonstrates that the impacts, the synergies, co-benefits (and trade-offs) of certain practices are still to be clarified (Henriksen and Hussey, 2011). Although similar difficulties have been experienced with extrapolating science to predict responses for agricultural systems in other contexts such as water quality and environmental conservation, reducing SOC science to credible messages for land mangers is particularly challenging, not least because of the lack of immediacy in measurable impacts.

2.4 Salience

The importance of compatibility or 'goodness of fit' of innovations or measures in making them more acceptable to farmers is well established (Pannell et al., 2006, Wilson and Hart, 2001). Salience is a related concept but in the science-policy interface context refers specifically to how relevant information is to the needs of the decision maker. Actors can be expected to have different knowledge interests, so their criteria for what constitutes relevant knowledge differs (Hegger et al., 2012, Cash et al., 2002). Information that is timely and informs decision makers about problems that are on their agendas has high salience. This has long been recognised in different models and approaches to agricultural extension (Black, 2000, Rogers, 2010). In relation to soil carbon, the credibility challenges referred to above are played out in a wider setting of complex decision making for SOC management, where there are a range of barriers and opportunities, transaction costs and economic trade-offs to consider which can constrain the potential to enhance carbon sequestration (Dumbrell et al., 2016). These conflicting priorities have implications for producing information from science that is salient to users. Dumbrell et al. (2016) recognised this in their analysis of adoption of carbon farming in Australia where they identified the importance of communicating the co-benefits and the synergies of carbon farming practices with existing farming practices. In other contexts such as diffuse pollution researchers and policy makers have created win-win narratives to persuade land managers of the economic co-benefits of changing practices (McGonigle et al., 2012).

2.5 Legitimacy

Legitimacy refers to the extent to which knowledge production has been respectful of the divergent values and beliefs of stakeholders, unbiased in its conduct and fair in its treatment of opposing views and interests (Hegger et al., 2012, Cash et al., 2002). The need for processes to accommodate stakeholders' views, knowledge and priorities is recognised in agricultural research, as it is in community management settings where the democratic ideal of stakeholder participation is well established (Leeuwis and van den Ban, 2004). This is in part due to disengagement from scientific explanations of issues and problems because of the imposition of prescriptive and reductive models which do not meet peoples everyday experiences (Wynne, 1996). This resistance together with a general challenge to scientific superiority has favoured approaches based on the principles of consultation, empowerment and ownership of the problem (Lee and Roth, 2006). These emphasise inclusiveness, in which individuals have a legitimate right to influence processes that have a direct bearing on them. A range of concepts and research techniques are employed to help scientists elicit and respect land manager views and knowledge. These include different degrees of participation and stakeholder engagement, and enable some co-production of knowledge (Millar and Curtis, 1999, Carr and Wilkinson, 2005, Pohl et al., 2010, de Bruyn and Abbey, 2003). In the context of climate change, the importance of iterativity and of creating a dialogue between those producing and those using information, often through a brokerage organisation, have also been recognised, particularly given the complexity of the subject matter (Dilling and Lemos, 2011).

Being legitimate also means that the information is perceived to be free from political persuasion or bias. Specifically Sumberg et al. (2013) point out scientific interest in soil carbon management for mitigation cannot be considered neutral, and for this reason this new narrative is subject to contestation. In this respect, there is concern that where political interests drive certain agendas, they do not always reflect the interests of the land managers. This is apparent in the range of land manager beliefs and attitudes about the evidence and perceived relevance of predicted climate change impacts (Arbuckle et al., 2014, Prokopy et al., 2015, Fleming and Vanclay, 2011).

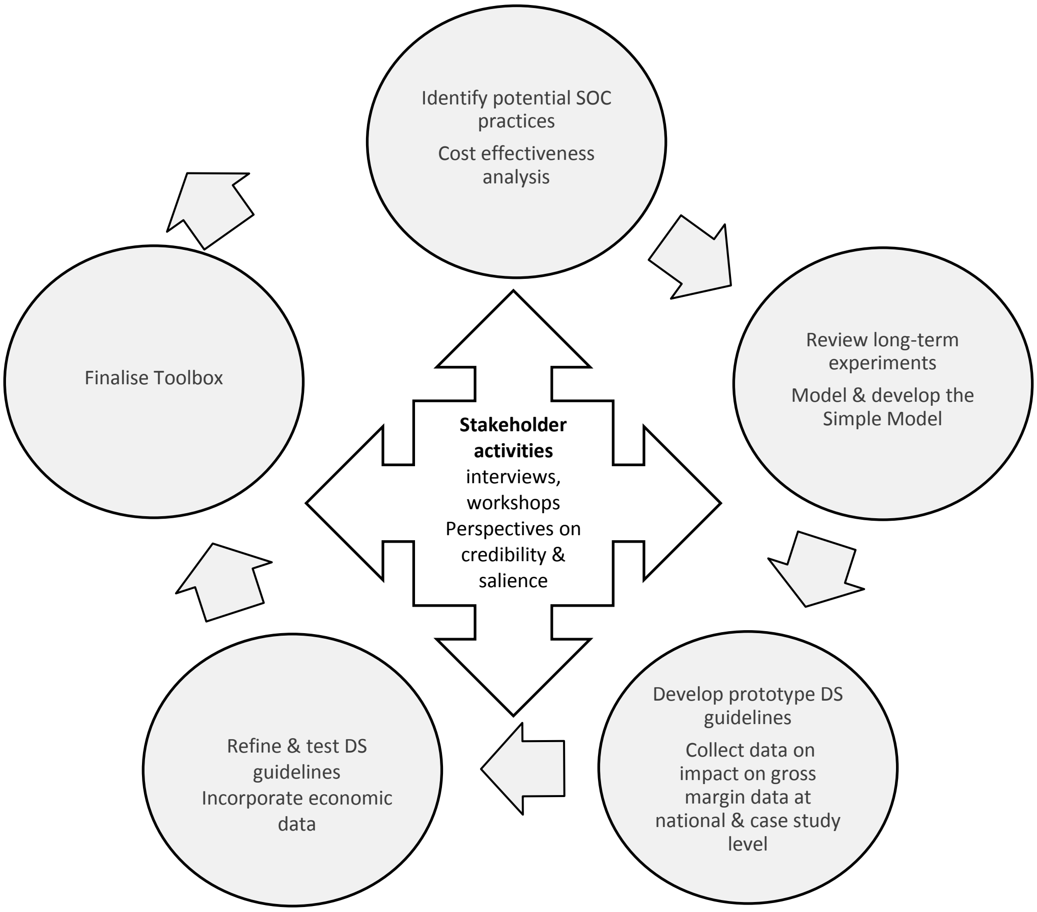
The significance of credibility, salience and legitimacy to producing and communicating information about soil carbon management from science to practice is clear. This paper aims therefore to situate analysis of a consultative process in the SmartSOIL project within this framework, specifically exploring the farming community stakeholder perceptions of these three attributes. Overall it aims to use these insights to inform more effective communication about soil carbon management from science to practice.

3. Context and methodology

The project sought to provide scientifically grounded recommendations and information to the farming community about soil carbon management. It developed an interdisciplinary approach, combining scientific insights and understanding of the farming socio-economic context, and had two overall aims:

- To identify agronomic practices (called here SOC practices) in arable and mixed farming systems that result in an optimised balance between crop productivity and soil carbon sequestration.
- To develop and deliver decision support guidelines for different European soils and categories of beneficiaries (farmers, farm advisory services, and policy makers).

Figure 1. The project's iterative methodology



Five sets of SOC practices (sharing similar principles) were identified as having the potential to increase soil carbon stocks and optimise productivity: cover (and catch) crops, crop rotations, residue management, conservation agriculture, and manure management. These were selected by drawing on an extensive review of research, project experimentation and project partner expertise (Wösten and Kuikman, 2014). The project used meta-analyses of data from European LTEs with a view to modelling and predicting the impact of these different practices on SOC and yield. This modelling was the basis of a 'Simple Model' (which aimed to predict the effects of crop management on developments in soil carbon and resulting effects on crop yield potential and response to nitrogen fertilization) which was used to develop a computer based decision support tool (DST) (Naumann et al., 2015). Cost effectiveness analysis was also conducted for these practices in different contexts (Sánchez et al., 2016, McVittie, 2014).

Understanding the perspectives and the information needs of the farming community, as well as barriers and incentives to implementing the SOC practices, was an integral part of this four year project, as was developing, testing and validating a range of decision support guidelines. This was achieved through stakeholder engagement in six case study regions in: Denmark, Hungary, Italy, Poland, Scotland and Spain using a series of interviews and participatory workshops throughout the project. This paper focuses on the findings from these activities.

Thus, although not explicitly recognised at its inception, the project was conceived on the basis that: authoritative scientific analysis could provide *credible* information on practices that store SOC; that an emphasis on optimisation of crop productivity as well as carbon mitigation (with cost effectiveness a key consideration) can provide *salient* information to the farming community; and that a process of iterative stakeholder consultation throughout the project enhances the *legitimacy* of the information produced.

Case study regions (Table 1) were selected to represent different bio-geographical (farming systems, soil type, SOC content, risk of soil carbon loss) and socio-economic contexts across Europe. Stakeholders in each case study included: agricultural advisers (from public extension and commercial services), farmer representative bodies (from agricultural chambers etc) and some leading farmers, research practitioners and policy makers (different levels of officials and decision makers with an interest in soil or climate). These categories are loosely defined as in practice they are blurred with some actors playing new hybrid intermediary roles. Project case study partners, themselves linked to agronomy and advisory institutions, used their professional networks and existing relationships to identify and purposely select a range of stakeholders from the categories listed above. These stakeholders did not have any particular expertise or prior exposure to soil carbon initiatives but were selected on the basis that they could comprehend and express a view about the subject. None of the case study regions had schemes or measures in place specifically targeting soil carbon management.

In a preliminary consultation, 68 stakeholder interviews (face to face and telephone), were carried out by case study project partners (approximately 10 per case study). These were preceded by seven pilot interviews in UK. In total 39 advisers, 24 policy maker/decision makers and 5 others (research practitioners and decision makers) were interviewed. In this early research phase interviewees were asked about the farming community's level of awareness and implementation of SOC practices in the case study region and about barriers to and incentives for their implementation. Their views on what information is used and/or needed to assist them in implementing the five SOC practices were specifically sought. The interview schedules were developed referring to the literature and expert knowledge about information needs, barriers and incentives for soil and mitigation, management practices (as referred to in Section 2).

The results of this consultation were fed back into the project's scientific processes of modelling, cost effectiveness analysis, and into the scoping and development of formats for decision support guidelines. Following this, two sequential stakeholder participatory workshops were held in each case study, with the same interviewees as well as additional stakeholders, including farmer representatives attending (with 5-20 stakeholders in each workshop). Each interaction allowed stakeholders to evaluate and feedback on the project outputs in a cycle of analysis, evaluation, feedback and refinement. This iterative process is shown in Figure 1. Stakeholders consulted are listed in Table 1.

Table1. Case study stakeholders engaged in interviews and workshops throughout the project

Case study regions and typical farming systems		**Adviser**	**Farmer represent.**	**Policy maker**	**Research practitioner**	**Adviser-policy maker**
Zealand Denmark Cereal and livestock	interview	4		3		
	WS1	7		1		
	WS2	3	2			
Central Region Hungary Large scale Cereals, small dairy, mixed and horticulture	interview	5		2	3	
	WS1	17		3		
	WS2	5	4	5		
Tuscany Italy Large scale wheat, olives, vines	interview	3		5		1
	WS1	2	3	2	3	
	WS2	2	4		2	
Mazowieckie Poland Small/medium scale cereal, orchards	interview	13		4		1
	WS1	14	3	4		
	WS2	8	3			
Eastern Scotland Large-scale cereal and potato/ arable, mixed farming	interview	7		5		
	WS1	5				
	WS2	N/A	N/A	N/A	N/A	N/A
Spain Andalucia Large scale olives **Aragon** Rainfed and irrigated crops	interview	6		5		
	WS1	4	5	1		1
	WS2	3	20			
UK pilot	interview	4		2	1	

Standardised interview and workshop methods were used in all case studies, the latter included presentations followed by participatory exercises, and a ranking exercise in Workshop 1 to ascertain participants' views about preferred information formats (from a list that included: DST, real life examples, GIS maps, videos, podcasts, factsheets, interactive social media). Data was collected by project partners in each case study using a common format and method. Interview and workshop data was collected as audio recordings and written notes. Interview data were transcribed and translated into English; workshop data were used to prepare a workshop report which was then translated into English. Analysis of all interview transcripts and workshop reports was then undertaken by the case study coordinator by identifying and manually coding common (repeated) themes across the case studies according to recognised methods (Ryan and Bernard, 2003). Credibility and salience, and legitimacy emerged as strong recurrent themes out of the data. The expression of these themes differed subtly in the case studies but it was possible to draw these together under common constructs. The interview questions and subsequent workshop topics were framed by some *a priori* understanding of the issue (as described above) however the three broad themes were not anticipated before analysing the data.

Results from both the interviews and the workshops are presented below, structured around these the three themes with an emphasis on advisers' views. The analysis also draws, in part, on the project scientists' interpretations of the process gathered in meetings. Attention is directed in this paper to how the stakeholder views informed the scientific project process and helped to shape the decision support guidelines for farmers and advisers. The project processes and stakeholder input in developing a DST, the economic and cost effectiveness outputs, and policy recommendations are reported elsewhere (www.smartsoil.eu).

4. Results

In general terms awareness and use of SOC practices was reported as low in the case study regions. This is backed up by analysis of data from the EU-27 regions which shows limited implementation of SOC management practices (Sánchez et al., 2016). Not surprisingly, stakeholder awareness, understanding and implementing of SOC practices differed between case study regions due to different biophysical, farming, socio-economic contexts and institutional contexts, as reported elsewhere (Ingram et al., 2014b, Ingram et al., 2014a). In Denmark and Scotland there is a growing interest in the farming and policy maker community in soil health and the role of soil organic matter, and in some cases soil carbon, particularly amongst organic farms, innovative farms and large agri-businesses. In other countries, notably Poland, awareness and implementation remains low reflecting limited political interest. There is also variation in the extent of farmer awareness both between and within countries reflecting farmer age, educational background and farm type; while for advisers, their knowledge and awareness is related to the quality and institutional culture of the country's advisory service.

Although a number of views and issues were raised in discussions, reference to credibility and relevance of information about SOC practices which could provide an optimised balance between crop productivity and soil carbon sequestration were repeatedly made and these are reported here. Given the diversity of case studies and the number of respondents, it is not possible to fully elaborate on their range of views nor their different background characteristics and contexts. In these results shared and common views are drawn out and presented, although it is not the intention to suggest that the stakeholder categories in each case study represent homogenous groups of actors. The information needs, synthesised and framed round the three attributes, are shown in Figure 2.

4.1 Credibility

One of the main concerns expressed by interviewees was the perceived scientific uncertainty about the benefits of SOC practices. A common view, particularly amongst advisers, was that there is little scientific consensus about what are the best practices for enhancing soil carbon and yield under certain conditions. In Spain one adviser commented "*The scientific community is not yet in agreement and it will be difficult to achieve. Lacking concrete analysis all over Spain, let alone Europe and globally".*

As one adviser in Denmark noted '*the cause and effect relationship between soil carbon and yield seem to be lacking or very theoretical'*. There is a perception that scientists themselves do not yet fully understand soil carbon dynamics and it is only when there is agreement amongst scientists that management recommendations will have real credibility. A research practitioner from UK (pilot interview) expressed this view saying "*One of the problems is that there is so much uncertainty about carbon at the simplest level. It would be helpful to have consensus in the scientific community first of all".*

Respondents referred to debates about the efficacy of different practices for sequestering carbon and for enhancing crop productivity and the fact that a systematic assessment is missing. As a result advisers are left uncertain about what recommendations to make, as this one from Spain explains "*Even 'experts' [like him] don't know which practice to recommend to farmers when they ask "how can I conserve the quality of soil and mitigate climate change?". The practices are too complicated"*. Other respondents agree that there is a lack of clarity on what constitutes best practice. Advisers emphasise the need for certainty when they make recommendations, as one Danish adviser said "*What 'we believe' is not enough for the farmers"*, and an Italian adviser supported this saying "*At the advising level it is crucial to have proof, and evidence of the effects of a practice*".

Dealing with the issue of heterogeneity at a regional and at a farm scale is also a concern for researchers and advisers who point out that translating recommendations to the farm level is complicated by variable local conditions. According to a Spanish respondent:

> *There already exist mitigation measures but there is no concrete process for their implementation depending on the specific requirements of each farm. We have to be aware of different areas and different practices. What might apply to one farm will not be appropriate for another*.

Most respondents stressed the importance of evidence when providing information about practices, however, there were differing views about what constitutes evidence. While the advisers look more for scientific validation (cause and effect relationships) and seek the authority of the scientific knowledge producing process, farmers are described as largely uninterested in scientific explanation, preferring to look to their own experiences and those of other farmers for proof. This is illustrated by this Spanish farmer representative's comment, "*Although many farmers do not understand the scientific knowledge, they clearly see the results of the practices in the field*". This view is widely supported, in Hungary for example an adviser remarked that "*Real life experience is more powerful than other information channels*" while in Poland farmers apparently distrust theoretical information but are more open to solutions that have already been tested by other farmers. Others suggest that this experiential knowledge prevents the acceptance of scientific knowledge. According to one Danish interviewee, and supported by a respondent in Italy, "*Regardless of the scientific validity, farmers act on their gut feelings, not rationally, and are not always open to other inputs*".

In line with these views, an exercise conducted in the Workshop 1 to identify the most effective way of communicating the benefits of SOC practices to farmers, ranked real life examples as the highest in all but one of the case studies, and factsheets as second highest, (videos and DSTs tended to be ranked next depending on the case study, social media was the least preferred in all workshops). The preference for factsheets reflects the view articulated by this Scottish respondent that, "*hard copy* *technical notes are still the most useful as they are tangible and familiar to farmers and can be discussed with an adviser in the field*". Others agreed that technical notes which provide proof of the benefits are important, as a Polish farmer representative remarked:

> *Farmers are not expecting any theoretical data presenting the reasons why the selected actions should be launched; they want specific information on what steps should be taken to implement a given measure and what effects (especially short-term) they will have*.

Respondents from other case studies concurred saying that the most useful materials for farmers give concrete guidelines on farming practices. They suggested that manuals and factsheets provide evidence by showing a positive impact, as one respondent in Spain said "*Farmers need documentation that a certain change or practice will either increase output or reap other benefits in terms of savings*". Respondents also tended to agree that it is essential to simplify the information and use the 'right' language in order to communicate a complex message to local situations.

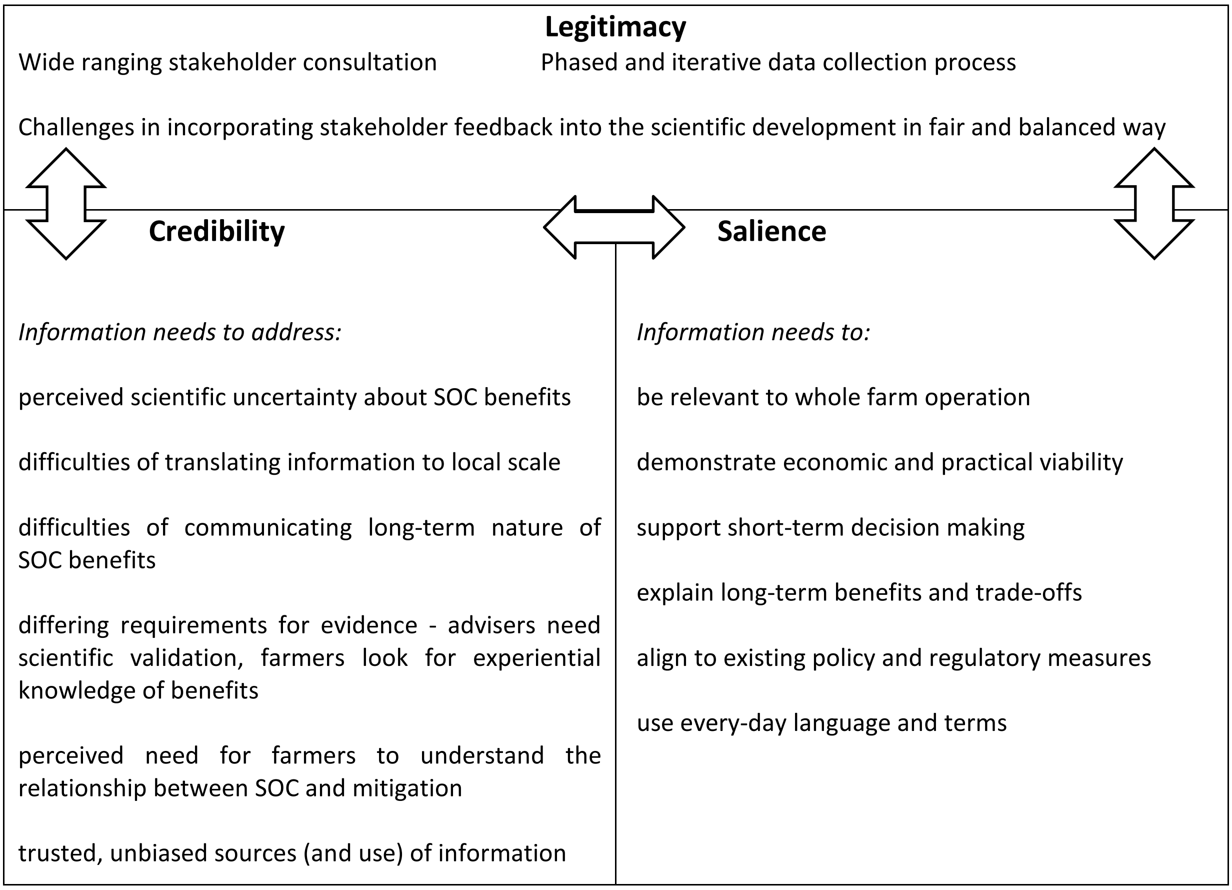
One Polish adviser however, argued for a different approach, saying that uncertainty expressed by advisers and farmers about carbon reflects their poor understanding of its significance for climate change mitigation. He suggested that, "*priority should be given to the development of materials presenting relations between agriculture and climate protection and the resulting need for higher carbon sequestration*". In his view this explanation would provide good foundations on which to build a credible message about mitigation practices. In accordance with this, a policy maker in Spain suggested that building an understanding of scientific principles is fundamental to communicating scientifically complex recommendations:

> *To farmers, we have to go back to explain the carbon cycle, they understand completely as they have seen the results and worked in the field for years, but they are lacking technical knowledge. If they are aware of the carbon cycle, they would be less inclined to employ bad practices. Only once they have a good scientific knowledge base, then we can start to include mitigation methods. Farmers don't know technically why they do what they do.*

These comments show the different and sometimes contradictory perspectives on the need for, and the constituents of, credible information about soil carbon for land managers. These differing views cannot be explained by any particular adviser or farmer characteristic, although the advisers who were sufficiently well informed or science-literate to question the science were all from the four western European case studies. Additional comments also revealed that some elements (observation at practical demonstrations, tangible information, simple language) are equally pertinent to both credibility and salience.

With respect to the trustworthiness or believability of the information, some interviewees perceived policy makers' knowledge and action to be based on something political rather than scientific information. One stakeholder in Italy for example, expressed concern that policy makers might misinterpret and use project outputs as evidence to support burdensome policy measures. The potential manipulation of scientific evidence thus is a further dimension of credibility.

Figure 2. Dimensions of credibility, salience and legitimacy in relation to information on soil carbon management



4.2 Salience

Information about SOC practices was questioned by many respondents according to its relevance to day-to-day farm activities and priorities, the time and spatial scale of operations and impacts, economic viability and regulatory measures. Some interviewees felt that scientists, and the policy makers they inform, are removed from 'the real world'. In Spain, for example, one adviser remarked:

> *Farmers know their practices well. You have to break down barriers between research and day-to-day practice of farmers. Even if the scientific community come to a consensus on best practice, it is likely that the practices defined will be so far removed from current practice that they [farmers] won't implement it. If the messages we want to communicate do not convey economically viable ideas, then they will be worthless.*

This shows that relevance of information to the farm operations and business is an overriding concern for farmers. Farmer judgment (and hence the judgements of the advisers who support them) of scientific information takes place in a wider context of decision making where economic viability is central. As put by one Italian adviser "*All management practices should be evaluated by the criteria: What does the farmer gain? Not by what does the soil gain*?" Interestingly this remark suggests that soil benefits are not always equated with business benefits.

Currently in the case study regions, there is no demonstrable commercial or policy incentive for farmers to consider the SOC practices. Consequently managing soil specifically for soil carbon is seen as insignificant, as one Polish adviser explains "*Climate protection is not a priority for Poland …….*

Farmers have far more pressing issues – how to maintain a profitable production, rather than actions to protect environment or climate", a sentiment reiterated in other case studies. Demonstrating economic viability of practices therefore becomes paramount, as this farmer representative from Spain remarked:

> *Farmers take decisions primarily for financial reasons and if they are to implement mitigation measures they must be seen as economically advantageous and will be more effective if seen in terms on possible savings or losses of incomes.*

One of the difficulties of communicating economic advantages is the long-term nature of SOC benefits to soil and potentially to yield and farm business, as shown in this comment by a Polish policy maker:

> *Due to a low level of environmental awareness, farmers will not accept voluntary measures or activities that require immediate expenses, but bring benefits in the long-term. This is reflected in advisory services, as advisers are unwilling to promote such practices.*

This sentiment was echoed in all case studies where respondents stressed that any guidance or tool conveying long-term SOC gains for which economic benefits are difficult to demonstrate will be "*hard to sell*". Initial financial penalties (machinery, seeds etc) incurred when starting some SOC practices make the long-term argument less appealing. For this reason a Spanish adviser said "*Even if you put lots of effort in to convincing them that a certain practice will be good in the long-term, I think this will be fairly ineffective".* Clearly planning for long-term gains in productivity are not always compatible with the short-term decision making environment of farmers and advisers who look for current information (inputs costs, market, varieties and disease resistance, weather, policy measures and regulation) to plan the next season or the next rotation. As one farmer representative from Hungary noted, farmers will be more interested in information to help them to decide "*whether you remove the straw this year or not*" than in a long-term perspective.

Aligning information about SOC practices with existing policy measures was also identified as important. However, most current measures (some cross compliance GAECs) only indirectly relate to soil carbon. Farmers in Hungary and Poland are described as being overly concerned with support to allow them to comply with regulations, as one adviser in Poland explained "*Farmers do not expect advisers to provide them with technological information. They want support on how to fulfil the EU requirements"*.

Nor is soil carbon part of the farmers' or advisers' vocabulary or every-day language, since it is still a relatively new issue for farmers. Although they are familiar with soil organic matter which is universally recognised as relevant to soil quality and crop productivity, the benefits of soil carbon and the functions it provides are not that well recognised or considered relevant. Indeed, some advisers pointed out that some farmers' interest in the soil itself is still limited, illustrated in this Scottish adviser's comment "*we're finding people that aren't carrying out a soil analysis, far less than knowing what their carbon content is*".

Advisers tended to agree that information should not just focus on individual practices, as in reality farmers apply these in combination, for example, residue management, cover crops and rotations are often integrated. Similarly they commented that information on a single aspect, such as soil carbon, is not helpful since in soil management, physical, biological and chemical considerations overlap. Consequently, as one farmer representative in Italy remarked "*information which is too specific [i.e. soil carbon] and communicated as an isolated issue is doomed to failure".*

4.3 Legitimacy

4.3.1 Stakeholder engagement

The intention was to consult a range of stakeholders who could represent both their own and farmers' divergent values, beliefs, and information environments. Consulting advisers and representatives of farmers, rather than talking to farmers themselves, clearly has some limitations. However, this was considered the best approach given the time and resource constraints of the project and the fact that these stakeholders (and advisers in particular) are often highly attuned to farmers' priorities. The results support this choice of stakeholder, as they reveal good insights into the farming community and experience of a wide range of farmer types, existing management practices and contexts. The results also show that, although the process uncovered a range of values, concerns associated with different actors, there was enough commonality at one level to suggest that the process had been sufficiently thorough and fair with respect to the breadth of perspectives.

Furthermore a phased and iterative process involving repeated face to face dialogue in interviews and participatory workshops with some of the same stakeholders presented opportunities for continuity, relationship building and project engagement. However, not all stakeholders readily engaged with such processes and case study partners experienced some difficulties both in recruiting and maintaining continuity due to other pressures on their time as well as a general disinterest in the topic. In these situations the case study partners were adaptable and arranged for alternative consultation methods, or alternative stakeholders, where possible.

4.3.2 Incorporating feedback

Whilst obstacles with stakeholder engagement could be addressed to some extent, incorporating stakeholder feedback into the scientific development of the project in a fair and balanced way proved more problematic. With respect to credibility the stakeholder views about uncertainty and their demand for clarity, different forms of evidence and proof presented some challenges for the project and for developing project decision support guidelines.

A comprehensive scientific review of long-term experiments in the project did not reveal with any certainty the expected relationship between SOC and yield for the selected SOC practices which would have provided the clarity that some stakeholders sought. This led some project scientists to question established thinking and to reframe the ambitions of the project to some extent. One summed up his frustration saying "*we want to believe that there is a clear causal relationship between soil carbon increases and yields but the review does not show this*". Furthermore, although the project scientists agreed that the central principles of managing soil carbon to benefit soil functions could be identified, they wrestled with transferring these principles into definitive decision support guidance applicable to the different spatial and temporal scales that farmers operate at. The problems in communicating the uncertainties involved, outside their usual boundaries of scientific protocols, were summed up in a frequent expression used by scientists, "*it depends*". This caution demonstrates their reluctance to provide recommendations unless it can be done "*with confidence*".

The scientists, guided by the project objectives and their own interests, also, not surprisingly have a different view to the stakeholders of what constitutes relevant information. Although keen to produce useful information for farmers, they regard the issue through the lens of soil carbon and all the functions it supplies. Being asked to address stakeholder feedback, challenged them to consider the different interpretations of salience.

Notwithstanding this dissonance, the project modelling and other activities did build on and enhance the body of existing knowledge by developing new scientific principles, a Simple Model as a basis for the DST (Olesen, 2014), and cost effectiveness assessments of practices and impact of practices on gross margins at case study region and farm level (Sánchez et al., 2016). These all provided the scientific underpinning for the decision support guidelines (see Figure.1).

Taking into account varied stakeholder views about what constitutes credible and salient information and their associated preferences for different information formats, it was clear that a one-size-fits-all approach to decision support was not appropriate. As such a Toolbox of different materials was developed comprising Real Life Case leaflets for each case study (with accompanying videos), FactSheets on each of the selected SOC practices, a DST, policy options, maps and scientific outputs (www.smartsoil.eu). Figure 3 shows how stakeholder feedback shaped the Real Life Case and FactSheets design and content, the development of the other tools is reported elsewhere (Naumann et al., 2015). Real Life Cases and FactSheets catered for the different forms of evidence identified as important, the former were developed for those (mainly farmers) who favour experiential evidence and the latter for those (advisers and some farmers) who prefer evidence explained in terms of validated causal relationships and scientific principles. Economic data was a key element in each of these decision support guides with costs and benefits of practices and impact on gross margins presented so that synergies and trade-offs could be judged. Both Real Life Cases and FactSheets use language and terminology familiar to farmers and present the key messages within the context of managing the whole farm system. These decision support guides were scoped following the interviews, drafted after Workshop 1, reviewed and evaluated in Workshop 2 and then adapted and finalised accordingly. Feedback on the draft guides, although mostly positive, was sometimes contradictory, demonstrating the difficulty in carrying out a truly legitimate process when diverse views are expressed.

5. Discussion

With reference to Science and Technology systems Cash et al. (2003) argue that traditionally scientists have overestimated the importance of credibility focusing on how to create authoritative, believable, and trusted information, and in doing so under-valued salience and legitimacy. In this project, although establishing scientific credibility was central to the aims, the objectives and methodology also took account of stakeholders' interpretations of credibility and salience, and of legitimacy. The results illustrate the need to pay attention to stakeholder assessment of these attributes, but also highlight some challenges in doing so.

Overall, the extensive stakeholder consultation showed that the notion of the science-farm divide is too simplistic, as recognised elsewhere (e.g.Vogel et al., 2007). The picture is more nuanced than the polarised term suggests with a number of actors, sectors, dimensions, domains and levels of activity involved each with different interpretations of the nature and extent of credibility and salience required when producing information. These are played out differently in the project and in each case study according to the role of the stakeholder and the regional and local contexts. This reflects the complex knowledge systems that science and practice actors operate within and has implications for information provision.

5.1 Credibility

The results presented here show that credibility is multi-dimensional with stakeholders referring to different criteria to assess what, for them, is valid and believable. Scientific plausibility has long been the currency of scientists but this research reveals the significance advisers place on this. This was articulated in terms of perceived scientific uncertainty and inadequacy of the technical evidence and arguments, which they felt undermined the validity of any claims and therefore potentially their advice to farmers. Uncertainty is a fluid concept and has a number of dimensions, one of which is confidence, a term frequently used by stakeholders and scientists. This corresponds to Sigel et al.'s (2010) notion of uncertainty (when a person lacks the confidence about their knowledge relating to a specific question) which they place on a spectrum between certainty (where they have confidence) and a lack of knowledge. Uncertainty is known to challenge the authority of climate science. The way in which scientists communicate uncertainty, and the boundary devices they use, affects the perceived authority of the science (Shackley and Wynne, 1996). In this respect Van der Sluijs et al. (2008) contend that the quality of evidence for complex and contested issues is a function of the scientific processes behind it. They argue that framing of the problem, the narrative for the solution, the review and interpretation of results, the distribution of roles in knowledge production and assessment, and the function of the results in determining the policy are important for the knowledge becoming either 'contested' or 'robust'. Reference by advisers to the "scientific community" as the source of uncertainty reveals a further facet of credibility. This is significant since high credibility sources are known to be particularly important when messages are complex and there is little available experience (O'keefe, 2015). According to respondents, farmers place less emphasis on scientific explanations, however, it is possible that farmers rely on and trust their advisers to validate the science for them, this is known to be the case when the messages or topics are complex (Ingram, 2008, Feder et al., 2004); and where farmers require 'definite' advice, as opposed to what the perceive as 'vague or contradictory' information from scientific sources (Holloway, 1999).

This distinction between farmer and adviser interpretations of credibility is clearly very broad and does not capture the heterogeneity of their knowledge orientations. Previous work, for example, has shown that farmers utilise quite different criteria to determine the reliability and applicability of new information (Raedeke and Rikoon, 1997), as do advisers (Ingram, 2008); while for achieving carbon sequestration, different sorts of land managers have been shown to place differing emphases on the robustness of scientific evidence (Dilling and Failey, 2013). However, in this project this broad distinction has been a useful heuristic in steering the development of the decision support guidelines to ensure that differing information-use tendencies are catered for.

These results raise the wider question of how to promote management where evidence is perceived as weak. Cash et al. (2002 p.4) point out "Credibility is hard to establish in arenas in which considerable uncertainty and scientific disagreement exists, either about facts or causal relationships". Achieving multiple benefits from managing soil carbon has become part of a new persuasive narrative however it is clear that there is still scientific debate, particularly when it comes to providing convincing evidence about the benefits of practices at the farm level. This is aligned to discussions around 'contested agronomy' where political framings steer the promotion of practices, such as conservation agriculture, despite weak evidence (Sumberg and Thompson, 2012, Whitfield et al., 2015). Furthermore some commentators suggest that uncertainty can lead to or justify inaction. Fleming and Vanclay (2011) for example observed what they called a discourse of questioning in which farmers emphasised aspects of uncertainty or incomplete knowledge in relation to the complexity of climate change. These farmers avoided further attempts to find information and waited until an answer could be legitimated by more scientific endeavour.

5.2 Salience

Fundamental differences in the characterisation of soil carbon management in relation to focus, language, approach and spatial and temporal scales were revealed, showing how the farming community and project scientists employ different criteria about what constitutes salient information. Stakeholders identified the need for information to be aligned towards farmer priorities and convey "*economically viable ideas"* rather than framing it around carbon or climate change mitigation which is currently largely irrelevant to farmers. Furthermore, while project scientists put carbon at the centre of their research, farmers are described as taking a whole farm view and not singling out isolated aspects. As previous researchers have shown, scientists dealing with soil are often concerned with one small element of the farmers' world, they disaggregate the different components and in doing this cannot provide information relevant to the operation of wider farming system (Liebig and Doran, 1999, Ingram et al., 2010). In dealing with this the decision support guidelines present information on the benefits as well as the synergies, co-benefits and trade-offs of carbon management and ensure this is relevant to the whole farm context (Figure 3).

Salience can be increased when the scales and reliability of the information are aligned with the scale and nature of the decision (Cash et al., 2003). However, matching information and decision making with respect to time and scale is problematic when managing soil carbon. Soil carbon responds slowly to changes in agricultural management, in ecosystem terms it is what is called a 'slow' variable whereas crop production (which is shaped by soil carbon) is a 'fast variable' (Walker et al., 2012). Communicating this relationship and such a distinction in immediacy is difficult. The challenge of providing information that explains and makes the long-term benefits of accumulating carbon relevant to short-term operators is clear; farmers and advisers look for evidence of immediate benefits, whilst science demonstrates SOC change and subsequent soil function and yield benefits in decadal terms using long-term experiments and models. This tension is demonstrated in studies of land managers' attitudes to soil health and productivity (Bennett and Cattle, 2013) and in many other contexts where short-term motivations (and information needs) override long-term strategies and benefits, for example, on-farm conservation (Siebert et al., 2006) and climate change adaptation (Bradshaw et al., 2004). However, research also shows that farmers are used to longer term strategic decision making (crop selection, equipment investments, or land purchases) (Stone and Meinke, 2006) and are motivated by security and long-term farm viability (Siebert et al., 2006). In this respect the potential for applications of seasonal weather/climate information to tactical and strategic decisions has been recognised (Prokopy et al., 2015). Arguably therefore, information on the long-term benefits of improved soil function, and the sustained crop productivity this brings, can be useful to farmers/advisers. As such the decision support guidelines produced by the project describe both short and long-term impacts, both in quantitative (yields, costs etc) and qualitative (increased resilience, confidence and learning) terms.

Matching information with the scale of the decision is equally difficult, as it involves translating scientific information (often from uniform experimental plots) to the finer spatial scale of the farm. Such alignment is complicated by the inherently variable nature of soils and the environmental factors, including climatic conditions and management regime, which affect SOC stocks. This is a common experience since science tends to utilise reductive models in which it assumes that people have common interests and contexts which are definable by science. The project struggled with developing simple information which has wide applicability and yet meets land managers' needs for guidance on incorporating carbon into decision-making at the local level. This is a recurrent problem in formulating soil management guidelines (Bennett and Cattle, 2013). Real Life Cases developed in the project overcome this problem to an extent, in that they are illustrative of certain local conditions, they are however inevitably limited in the number of situations they can represent; meanwhile the FactSheets have wider relevance but rely on users to translate overarching principles to local situations.

5.3 Legitimacy

A key part of achieving legitimacy was the project's iterative methodology. Iterativity has been shown to be an important element of both science-policy (Sarkki et al., 2015, White et al., 2010) and science-practice interfaces, especially when uncertainty is high and values are contested (Carberry et al., 2002, Oliver et al., 2012). The research reported here demonstrates that a short-term project setting can provide an interactive space where repeated dialogue enables the scientists to understand the decision contexts of the information users. Participation alone does not guarantee legitimacy, differences in the nature and level of participation, and in particular whose views are sought and taken into account, affected the process, as observed in other contexts (Neef and

Neubert, 2011). As well as managing participation, managing feedback and expectations was also important in this project. There were challenges of incorporating wide ranging and sometimes contradictory stakeholder views in a fair way, and in this case the question arises, not only "Is the process fair? But, if so, "Fair to whom?" Adaptability and responsiveness were key in dealing with these issues and developing decision support guidelines suited to different user needs, and that met both scientist and stakeholder criteria for acceptability. Furthermore, as commentators note, however consultative an approach may be, ultimately choices are made about which problems and potential solutions will be considered and which ones will not and this is clearly the case in a research project which has a defined remit and outputs agreed with the funders and steered by political agendas (Leeuwis et al., 2004, Cash et al., 2003, Giller et al., 2008).

In summary although credibility has been portrayed as solely a scientific interest and salience and legitimacy as 'societal' interests (Cash et al. 2003), this research has revealed that stakeholder and project partners have criteria related to all three attributes as found by other scholars (Hegger et al., 2012, Roux et al., 2006, White et al., 2010). It has also shown that criteria differ between and within stakeholder groups. The challenges this presents for providing decision support guidelines about soil carbon management are evdident and akin to those identified in wider elements of communicating climate change. As Moser (2010) observes individual information needs are multi-dimensional, it is too simplistic to assume individuals merely lack information or understanding.

5.4 Dynamic interplay between the three attributes

The results also reveal an interplay between stakeholders' views on credibility and salience and between these and the legitimacy provided by the project methodology. This is in-line with other research which has shown that the three attributes are, not only tightly coupled, but often in dynamic tension (Cash et al., 2002, Hegger et al., 2012).

Increasing legitimacy through extensive consultation across a range of European stakeholders potentially had some negative effects on the salience of the information produced by the project. Stakeholders' different interests and priorities led in some part to diluting and re-framing the issues in a way that made some information irrelevant to some stakeholders; as what is considered important or valued in one case study was not relevant in another. Although it was possible to refine and orientate the salience of Real Life Cases towards particular interests at the case study level, this was more challenging for EU wide FactSheets, where accommodating all the feedback risked them becoming too generic. When it comes to reconciling stakeholder views and providing relevant information, inevitably a balance must be struck according to the scale of delivery.

Efforts to increase legitimacy can also decrease credibility. Given the space to articulate their views, some respondents exposed, and arguably emphasised, the scientific uncertainties about the potential benefits of the SOC practices, possibly because of personal beliefs, as found elsewhere with climate change communication (Moser, 2010). Participatory processes to allow legitimacy provide opportunities for stakeholders to express doubts about the way research is produced, validated and communicated and this can represent some fundamental difficulties for scientists (Sumberg and Thompson, 2012, Vogel et al., 2007). There are also issues of raising expectations amongst stakeholders through consultative processes, and of the difficulties in achieving a balance between credibility and salience where scientific uncertainties compete, and have to be reconciled, with the certainty of everyday farming challenges and priorities. Vogel et al. (2007) also point out that stakeholders often have high expectations as to how soon decision–specific information becomes available, meanwhile scientists may want to err on the side of caution referring their work to the peer review process. Legitimacy can also decrease credibility if the science is seen as being 'tainted' by stakeholders with a particular interest who might bias the process (Cash et al., 2002). In relation to this some stakeholders expressed unease about policy makers input and their potential misinterpretation of the information. This is seen to be a concern in rural settings where policy makers are described as using the discourses of certainty and technical expertise as legitimate arbiters of technical measures and environmental standards (Pretty, 1995, Whatmore, 2009).

6. Conclusion

This paper sought to examine the potential disconnect between science and practice in the context of a project concerned with creating and communicating information about soil carbon management. The results suggest that, although there are potential boundaries between the scientific ambitions of the project and the potential end-user requirements, there are opportunities to overcome these. Enabling multiple perspectives to be considered, incorporated and accommodated through a legitimate process, revealed the importance, and the different dimensions, of stakeholder views on credibility and salience. The impetus on land managers to sequester carbon is likely to intensify. In order to support their future information requirements projects and programmes will need to consider such processes that can reveal, and act on, these attributes. This is particularly important given the complexities and contested nature of managing soil carbon. Stakeholders not only reveal their different criteria and priorities with respect to credibility and salience, they also question the narratives developing around soil carbon, highlighting perceived weaknesses in the scientific evidence. This demonstrates the importance of providing opportunities for dialogue to engender greater understanding between science and practice, and in particular to reconcile the tension between credibility, salience, and legitimacy.

Beyond enhancing our understanding in the context of managing soil carbon, these results offer some wider insights for research in rural settings more generally. Although the notions of credibility, salience, and legitimacy have been recognised as important in a number of research contexts, the interplay between them has hitherto received little attention. Such relationships are important given that researchers are tasked with understanding an increasing number of scientifically delimited controversies in environmental and resource management which are being negotiated at the individual, community and societal level. This study shows that for complex problems there is a need for a more nuanced understanding not only of the processes of stakeholder engagement in research, but also the production, communication and framing of scientific evidence.

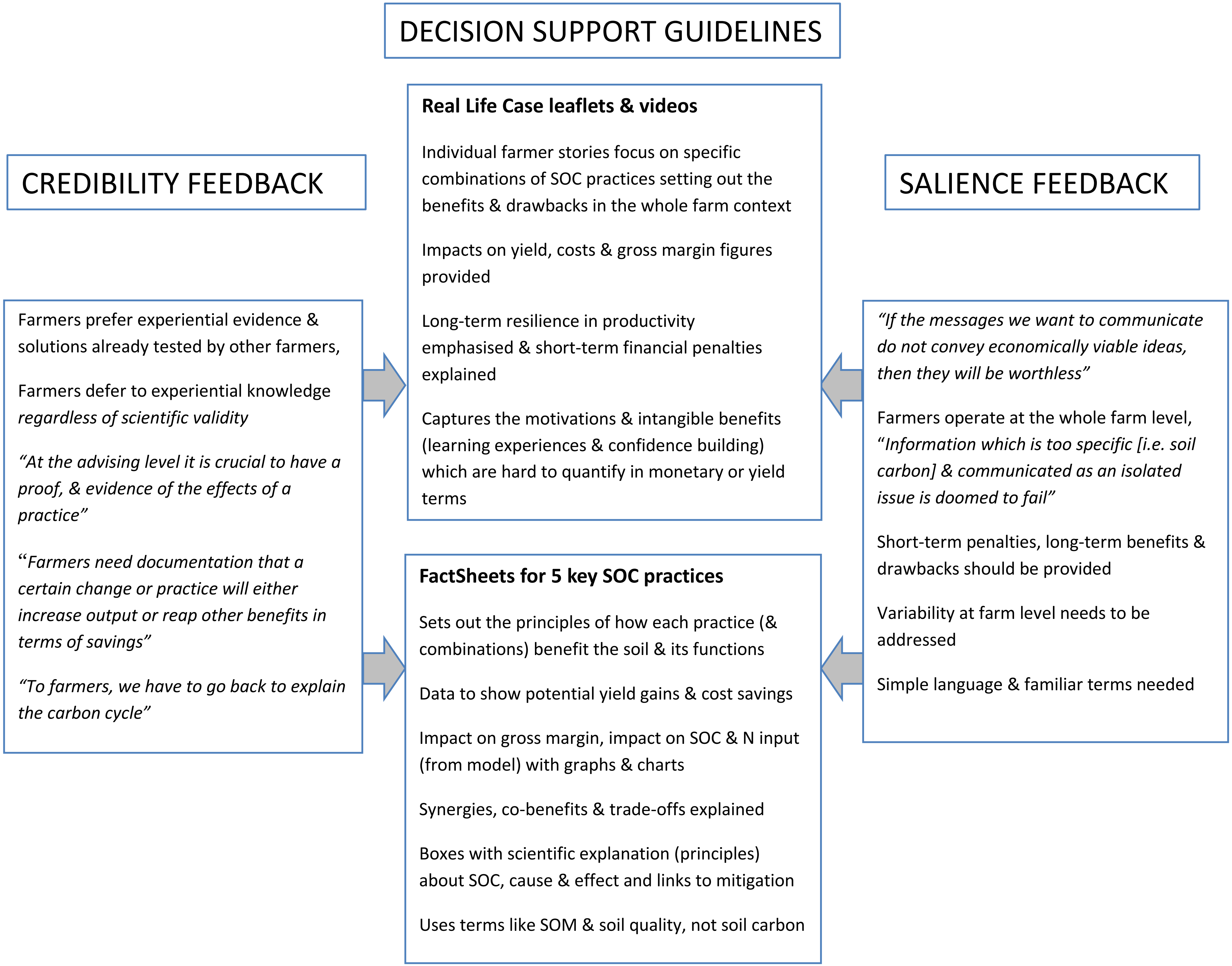


Figure 3. Development of decision support guidelines according to stakeholder perspectives on credibility and salience

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